REMARKS/ARGUMENTS

Favorable reconsideration of this application as presently amended and in light of the following remarks is respectfully requested.

Claims 1-21 are active in this application, Claims 1, 2, 6, 7, 8, 12, 13, 14 and 18 having been amended and Claims 19-21 added by the present Amendment.

In the outstanding Office Action, Claim 1 was rejected under 35 USC §102(b) as being anticipated by Driscoll Jr. et al (U.S. 5,067,162, hereinafter called "Driscoll") and Claims 2, 8 and 14 were rejected under 35 USC §103(a) as being unpatentable over Driscoll, as applied to Claim 1, in view of Hu et al (US 5,867,584, hereinafter called "Hu").

In light of the several grounds for rejection, the claims have been amended to clarify the claimed invention and thereby accentuate subject matter which is believed to be patentably distinguishing over the cited art. No new matter has been added.

Briefly recapitulating, Applicants' invention relates to an image template matching and more particularly to an evaluation value for determining at least one parameter of the template matching, the parameter comprising a location of a reference point, a size of the template and resolutions of first and second images.

According to an exemplary embodiment described at pages 27-28 of the specification, an evaluation value, which evaluates the magnitude of the matching error generated by the template matching, is calculated.

In the template matching, an area having the highest correlation with the template (matching area) is searched from a second image I2 making the reference area including the tracking point (i.e., the reference point as stated in the pending claims) in a first image I1 as a template. There should exist a true corresponding point in the second image I2 corresponding to the tracking or reference point in the first image I1. However, the point shifted from the true corresponding point may be regarded as the corresponding point by

noises or the like in the template matching and the area in the second image I2 having the shifted point may be regarded as the matching area.

The distance between the true tracking point in the second image I2 (corresponding point corresponding to the tracking point in the first image I1) and the corresponding point which is the result of the template matching is defined as a matching error. According to the embodiment, the upper bound of the average (average distance) of the relevant distance on the second image I2 is calculated from the first image I1 as the evaluation value of the matching error (See e.g., page 28, lines 6-9 of the specification). Since the second image is not necessary to calculate the evaluation value, it is possible to easily calculate the evaluation value in a short period of time. Usually, when S is a subset of a sequential set A, the element b of the set A as satisfying the expression of $x \leq b$ to all of x belonging to the set A is referred to as "the upper bound b" of the subset S. However, the upper bound used in the present embodiment is more particularly defined as next discussed.

It is assumed that that an image including the template (corresponding to the first image I1) is represented as f_0, the objective image in which the matching area having the highest correlation with the template should be searched (corresponding to the second image I2) is represented as f, and the pixel at the coordinates $p = (x, y)$ of the image is represented as $f(p)$. It is assumed that the reference point (tracking point) in the image f_0 is the origin O and the template is a window $W_0(O)$ whose tracking point is made as the center as shown in FIG. 7A. The template matching is a process for detecting that the template is moved to a window $W(p)$ (referred to as searching window) having a center point p within the searching range S.

It is assumed that a vector from the true tracking point in the image f (the true corresponding point corresponding to the reference point in the image f_0) to the corresponding point corresponding to the reference point in the image f_0 found by the

template matching (error vector) is e. When a certain image f is specified, the error vector e is univocally determined.

In order to find the upper bound, first, the probability P(e) that an arbitrary error vector e is generated is evaluated. This means that the incidence probability of the image f that the error vector becomes e is evaluated.

Next, as to all the error vector e which has the possibility of being generated within the searching range (error vector found concerning with a plurality of the image f), by adding the product of the magnitude of the error $|e|$ and the probability P(e) to it, the upper bound of the average distance as the evaluation value is obtained. The average distance means that the distance between the true corresponding point (tracking point) in the image f and the corresponding point found by the template matching is found on a plurality of the images f and averaged.

This evaluation value is analytically found by the calculation from the first image I1, specifically, by utilizing the error factors such as information of the first image I1, noises and the like. It is assumed that the change of the pixel value generated by the noises and deformations is according to the additional Gaussian noise of the dispersion σ^2.

As shown in FIG. 8, defining that the three areas W_1, W_2 and W_3 formed by the area of the template in the image f and the area in which the template is parallel displaced by the portion of the error vector e are $W_1 = W(O) \cap W(e)$, $W_2 = W^c(O) \cap W(e)$, and $W_3 = W(O) \cap W^c(e)$, respectively. W^c represents the complement of W. A block 501 in FIG. 8 is the first area to be the template, and a rectangular block whose true corresponding point is made as the center. A block 502 is the second area in which the block 501 is parallel displaced by the portion of the error vector e, and is a rectangular block whose point shifted from the true corresponding point is made as the center. The averages $\gamma_1{}^2$ and $\gamma_2{}^2$ of the

ratio of the pixel value within the areas of W_1, W_2 to the noise is defined by the following expression.

$$\gamma_1^{\,2} = \frac{1}{|\mathrm{W}_1|}\sum_{\mathbf{p}\in \mathrm{W}_1}\frac{\Delta^2(\mathbf{p},\mathbf{e})}{\sigma^2}, \quad \gamma_2^{\,2} = \frac{1}{|\mathrm{W}_2|}\sum_{\mathbf{p}\in \mathrm{W}_2}\frac{\Delta^2(\mathbf{p},\mathbf{e})}{\sigma^2} \qquad (1)$$

The difference $f_0(p+e) - f_0(p)$ between the pixel value of coordinates p = (x, y) in the image f_0 and the pixel value of the coordinates in which the coordinates are parallel displaced by the portion of the error vector e is replaced with Δ(p, e). Defining that the number of pixels of the respective areas are described as $N = |W(O)|$, $R = |W_2|/|W(O)|$.

The probability P(e) that the error indicated by the vector e is generated as a result of the template matching can be evaluated by the following expression:

$$\mathrm{P}(\mathbf{e}) \le \exp\left\{-\frac{1}{2} N E_{TM}(\mathbf{e})\right\} \qquad (2)$$

Provided that the following expression holds:

$$E_{TM}(\mathbf{e}) = \max_{0<\rho<1} E_{TM}(\mathbf{e},\rho) \quad ,$$

$$E_{TM}(\mathbf{e},\rho) = R\left\{\gamma_2^{\,2}\frac{\rho}{1+\rho} + \log(1-\rho^2)\right\} + (1-R)\gamma_1^{\,2}\rho(1-\rho) \qquad (3)$$

$E_{TM}(e)$ is non-similarity between the two blocks (the block 501 of the template and the block 502 that the block 501 is parallel displaced by the portion of the error vector e) shown in FIG. 8.

The average ϵ of the error generated by the template matching can be represented by the sum of the expectation on all of the error vectors e within the searching range as follows:

$$\varepsilon \le u = \sum_{\mathbf{e}\in \mathrm{S}} |\mathbf{e}| \mathrm{P}(\mathbf{e}) \qquad (4)$$

Where, u is the upper bound. When the template matching is performed using a certain tracking point (reference point) by this expression (4), it is possible to guarantee that

the magnitude of the average error (average distance) ϵ is u or less. This means that the upper bound u can be used as the matching error.

Thus, the template matching is capable of being performed with a high precision using the upper bound u evaluating the average of the magnitude (average distance) of the error of the template matching as the evaluation value with respect to the respective tracking point candidate/template size candidate/resolution candidate of the image by determining the parameters such as the tracking point (reference point), the size of the template, the resolution and the like.

The calculation procedure of the evaluation value u will be described using the flowchart shown in FIG. 9. In the processing of calculating this evaluation value, the value of the upper bound with respect to the candidate of the given tracking point (reference point) is calculated.

In step S401, the initial value 0 is substituted for u.

In step S402, the tracking point candidate which has been not yet processed is selected from the searching range of the given tracking points. Then, the error vector e from the tracking point (true corresponding point) to the selected tracking point (corresponding point) candidate is found.

In step S403, γ_1 and γ_2 are calculated from the given tracking points and the tracking point candidates selected in step S402.

In step S404, the value of ρ is selected from the values within the range of 0–1 so that the value of $E_{TM}(e)$ is maximized.

In step S405, $|e| \cdot \exp((-1/2) \cdot N \cdot E_{TM}(e))$ is added to the upper bound u.

In step S406, it is determined whether or not the tracking point candidates which have been not yet processed remain within the searching range. If the tracking point candidates

remain, step S402 is repeated, otherwise, the processing proceeds to step S407, and the upper bound u is output as the evaluation value to the given tracking point candidate.

Turning now to the cited prior art, Driscoll relates to verification of a personal identity by correlation of fingerprint images, which is not template matching. Driscoll merely teaches determining best-match locations within each verify region at which the image data is most similar to the image data of its corresponding reference section, and verifying the identity of the person claiming to be enrolled according to the degree of similarity between the image data of the best-match locations and the corresponding reference sections and according to the degree of similarity between the relative positioning of the best-match locations and the corresponding reference sections (see Abstract). Driscoll does not calculate, based on the first image, a difference between a corresponding point in the second image corresponding to the reference point and a calculated point in the second image which is obtained by the template matching. Driscoll at Col. 16, line 61 to col. 17, line 14 merely teaches correlation value between the trinarized image data of the reference section and the binarized image data of the verify fingerprint image.

Further, though Driscoll determines the best-match location, the best-match location for the primary candidate reference section 102 does not determine the reference point included in the template in the first image.

Hu merely teaches that the intensity distance of the specific test window is set to the maximum of the intensity distances of the color components (See for example, col. 6, lines 14-16). The maximum of the intensity distances of the color components is not the upper bound of average distance between the corresponding point and the calculated point, as recited in Claim 2.

In view of the above-noted deficiencies in the cited prior art, it is respectfully submitted that the outstanding grounds for rejection are traversed, and that the amended claims patentably define over the cited art.

Consequently, in view of the present amendment and in light of the above discussion, no further issues are believed to be outstanding, and the present application is believed to be in condition for formal allowance. An early and favorable action to that effect is respectfully requested.

Respectfully submitted,

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